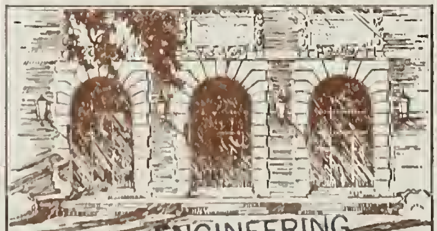

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APPLICATION OF COMPUTER TECHNOLOGY TO THE WORKING-DRAWINGS PHASE OF ARCHITECTURE

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Abstract

This paper describes the methods by which a computer system can be used in the working-drawings phase of architecture. Attention is given to discussing how architects can make use of computers and what is required of them. Major areas of concern are the computer graphics capabilities involved in drafting and interactive design.

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PREFACE

The purpose of this paper is to describe the methods by which a computer system can be used in the working-drawings phase of architecture. It is intended for an audience of architects (students or practioners). The scope has been restricted so that only working drawings are discussed in detail. All other information is presented as background material.

Although the body of the paper discusses how the computer can aid the architect, this preface concerns itself with what an architect must do to use a computer system.

Many non-computer people are at first apprehensive about using computers because they have heard and been involved in incidents which herald the coming of the automated age; where man becomes the slave of the machine because of the machine's unending stamina and superior ability to handle complex situations. The nightmare of Orwell's *1984* appears as an all-too-real possibility with today's endless progression of technological advances. Further trepidation comes from the potential loss of individuality due to use of computers to check and cross-check every aspect of our lives.

Though the preceding paints a dismal picture, there is no reason to suspect that today's technological advances will be any more misused than those of the past. To prevent the possibility, great care is taken to control computer use.

What the non-computer person cannot initially comprehend is the benefits computers bring to our society. Many of man's problems are too complex or too large for him to solve for himself, but he can tell a machine how to go about solving them. Urban planning represents an obvious example. Today's cities are changing faster than anyone ever dreamed and only computers can even attempt to predict their course. A field where the application of computers is not so obvious is architecture.

Architecture has traditionally been a field of the arts where thought and creativity are important. A digital computer appears to have no relationship with this area. The key lies in the fact that the thought process is composed of many sub-processes, each small enough to be analyzed and solved. The solution of each small sub-process is applied to the next sub-process until the entire problem is worked out. Computers are useful in aiding us in solving each of the smaller sub-problems of a larger problem. It is in this way that many computer programs can be used to solve a problem.

To the uninitiated architect, or worse yet to the architect turned off to computers by a previous bad experience in learning computer programming, learning to use a computer in practice poses a severe threat to the equilibrium of his practice; it seems that what he took years to learn will be fed into a machine and out will pop a design. Another feeling is fear; fear of having to learn yet another subject, computer science, that appears to be filled with an unbelievable number of facts.

To answer both threats simultaneously, the architect need not worry. The use of a computer in an architectural office should have little effect on his actual design process except for increased productivity and more thoroughly worked out designs. A computer can be used to present to the designer a series of solutions to a problem, but it is up to the designer to make the executive decisions that make a good design. There is also little to worry about in learning to use a system since, assuming no previous computer experience, most people can be taught how to obtain useful results from a computer-aided architectural system in a few hours. The architect has no programming to do; only providing data for the programs. He provides the data by working in his normal manner, except he is linked to a computer. He draws as he always did but now he is at a graphics terminal instead of a drawing board and uses equipment other than tracing paper.

Most people who come in contact with a computer-aided-design system daily view it as a positive development rather than a bother.

INTRODUCTION

While computers have been used for nearly 25 years, the first 13 years were devoted to doing calculations that previously were beyond the grasp of men. The primary thrust, then, was to develop bigger and faster machines in order to do more calculations; quantity was desired. During the last 12 years an equal desire for the qualitative use of computers has evolved. That is, while computers are very useful for "number crunching," they are not limited to calculations as their only product.

As the increased potential of computer technology was recognized, other disciplines saw that it could be applied to their areas of interest. A major effort in today's "applications" field of computers is devoted to developing architectural systems.

The first question that arises is, "Can computers do architecture?" The answer is no they cannot create architecture, but they can greatly assist an architect as he creates architecture. Of course the next question is "How?" To answer this question, one must review the process that an architect follows:

1. Assess the needs of the client and develop the objectives of the project.
2. Generate schematic design.
3. Develop the design considerations with respect to compatability between needs, trades, code requirements and the client's approval.
4. Develop the contract documents which include working drawings and specifications.

The methods by which a computer can aid an architect are stated here:

1. Computer graphics.
2. Thought organization programs that help in the assignment of priorities.
3. "Bubble diagram" programs that help establish the basic spatial relationships.
4. Spatial allocation programs that aid the designer in actually positioning the elements of a project.
5. Simulation and optimization programs that aid the designer in making intelligent decisions in the design development stage by providing accurate information about the design.
6. Contract documents; aid the designer in preparing the working drawings and specifications that are necessary to communicate his design concept.

   Text-editing systems allow the specs and contracts to be completely prepared with the aid of a computer.
7. Business management programs to keep track of who worked where and for how long, materials used and wasted, and all accounting necessary to run an office. The cost of doing a job can be accurately determined by a management system that monitors the entire design process.
8. PERT and critical path methods (CPM) are currently used in actual construction situations and are quite accurate. These methods are used to organize the ordering of materials,

determine the logical order of work and the manpower assignments. The programs minimize conflicts to minimize costs.

In recent years, the relationship between man and machine has improved considerably. One of the reasons for this better communication is the development of interactive computer graphics. Interactiveness gives the designer the capability to have an affect on something the computer is working on, while it is in progress. If, for example, the computer was calculating a plan configuration solution for a given building, the designer could interactively make changes, alterations or decisions about the plans being developed and thus change the way the computer was solving the problem.

It is the author's opinion that when a computer's capability to handle multitudes of small problems is coupled with a designer's ability to make broad decisions over complex information, better architecture will result.

BACKGROUND

Until the early 1960's, computer graphics consisted only of oscilo-scope applications in radar and other electronic equipment. An important development came at that time with the SKETCHPAD system of Johnson and Sutherland at MIT. This was the first time that a person could communi-cate with a computer in a graphical environment. This communication was accomplished by the use of two devices:

1. A cathode-ray-tube (similar to a TV) which electronically displayed beams of light on its screen.
2. A writing tablet which electronically sensed the position of a special pen on its surface.

The tracing of a pen over the surface of a writing tablet produced the image on the screen of the cathode-ray-tube. The screen also displayed images produced from sources other than the writing tablet such as the calculated image of a perspective drawing. In this case, the graphical devices were linked to a computer system. The initial image could be drawn by hand on the writing tablet, then transformation equation cal-culations were performed by the computer to determine a certain perceived image which was then displayed on the cathode-ray-tube screen.

The list of graphical devices has grown considerably with the develop-ment of flatbed plotters, digitizers, storage tube displays and other equipment that put computer graphics in reasonable financial reach of any size firm.

The net result of all these efforts, and the interest to architects, is that they allow a person to communicate with a computer in a graphical mode as well as the more familiar numerical or alphabetical modes.

A particular type of computer graphics system, an INTERACTIVE SYSTEM, merits discussion here. Interactive graphics systems allow the person using them to continuously communicate with a computer, and, therefore, allows the person and the computer to work "hand-in-hand" with each other. For example, the architect can be working on one design, ask the computer to show him other similar solutions, and then proceed in whatever direction he choses. Interactive systems are often referred to as conversational mode systems while architectural type systems are usually called interactive design systems.

WORKING DRAWINGS

Of all the applications of computers to architecture, the working-drawings application may very well have the greatest immediate benefit to an office. Since the working-drawings phase consumes 30-40% of the architect's time and fee, any percentage savings in that area can have a significant impact on his business.

It would not be an overstatement to say that a computer-aided system can be expected to take 25-50% less time than conventional methods. The increases in drafting speed because of computer graphics equipment allows the actual execution of the drawings to be performed in a mere fraction of the time it now takes. Probably only a few day's work would be required for a complete set of drawings. This time estimate is based on setting up for the drawings as well as the actual drafting by machine (the actual drafting time would probably be only a few hours).

Another very important advantage of using a computerized system is that it provides additional feedback to the architect about his design. At any given stage of the design, he can command the system to draw details of certain areas or floor plans or whatever intermediate graphical information he requires. This assumes that he has specified the room locations, construction materials, etc., so that the system has the data to make the drawings. In a conventional office, the working drawings have only one-way use, that is, the architect draws them to be used by someone else. He receives no benefit from the drawings while he is actually doing the design work. With a computerized system, he is able to

study the detailed aspects of the design at the time he is making the crucial design decisions. At this point, many problems that arise during a project can be foreseen and avoided.

Since a computerized system would produce uniform results, additional benefits are gained from standardization of all drawings and specifications. Both the client and the contractor will be able to better understand the working-drawings when all conventions, line weights, lettering heights and styles, and symbols are standardized. This is true for work done by any type of draftsman, with or without a computer. Such standardization must occur because the only purpose for working drawings is to communicate the assembly of a design. Using a computerized system increases the standardization of drawings because it eliminates the differences between draftsmen.

The following are ways in which a computer can be of assistance during the working drawings phase:

1. Drafting
2. Checking compatibility between systems
3. Access to manufacturers' data (Sweet's files, etc.)
4. Details for drawings
5. Access to information on previous jobs
6. Design aid for jobs in progress
7. Specifications and other contract documents

1. <u>Drafting</u>

Mention has been made of drawings done by a computer. This section tries to explain the process in detail.

The discussion falls into two sections that answer the questions:

A) What is the process?

B) How is it used?

A. Process Description

A computerized drafting system is simply a drafting machine attached to a computer. The drafting machine can be a plotting mechanism which produces drawings on paper or a cathode-ray-tube device from which photographs or microfilm may be taken. Of the two basic types, the plotting system has the most interest to architects. It produces reproducible drawings by drawing (with ball point or India ink pen) on a quality paper in the same manner that draftsmen do now. There is also a selection of line widths and ink colors available that are equivalent to the ink pen sets architects presently use. Some drafting machines have heads that can interchange pens so that it is possible to change pens during the drawing, while others must be stopped in order to change pen points or ink colors.

The commands for drawing the lines must come from the computer programs. The programs tell the machine where to put the pen on the paper and whether or not a line is to be drawn. The computer programs can specify commands for dotted, dashed or solid lines. All characters and symbols are drawn by a series of lines, the coordinates being calculated by the programs. Thus, the entire drawing, as determined by the computer, is fed to the drafting machine as a series of coordinate pairs and a code word telling the machine what type of line to draw. If no line is to be drawn while the pen is repositioned, the pen is lifted so no ink is put on the paper.

B. <u>Use of the Process</u>

There are two basic ways that an automated drafting system can be used. In the first, the draftsman must feed the plotting commands to the drafting machine. This is usually done through a small computer using a geometrical language. The language allows him to declare the coordinates of certain points and then to declare lines that connect them. He can also place symbols and headings by giving the proper commands. The following could be considered a small program to plot a box using an idealized geometrical language:

```
DECLARE POINTS P1<100,20>,P2<100,50>,P3<300,50>,P4<300,20>;
DRAW LINES L1<P1,P2>,L2<P2,P3>,L3<P3,P4>,L4<P4,P1>;
DRAW LABEL "BOX" AT <120,0>;
```

(This small program shows only how a box could be described using a geometrical language.)

The second method is by far the better method. It uses an interactive design system and a set of computer programs to calculate the geometrical language commands without bothering the architect. Any drawing that the architect has developed through an interactive design system can be fed to a drafting machine without his help. At the same time, the scale of the drawing may be changed and have the amount of detail that is shown reduced for an intermediate drawing. The latter situation is important because the designer may only want to see the basic floor plan without the complete detailed information of the full working drawing. The programs would be able to select the appropriate amounts of

detail desired by the designer. This process really frees the designer since the drafting phase is completely taken out of his hands. He is responsible for the design and material selections, and the computer takes care of feeding the proper commands to a plotting machine. In this way, an architect could view several possible perspective views before selecting the desired presentation views. (Movies are also being made showing sequences of views calculated and filmed frame by frame. These systems will probably remain too costly for some time.)

2. Checking Intersystem Compatibility

Integrating the various systems (structural, electrical, mechanical, etc.) of a building is a very important part of the design process. Because compatibility between systems must be established before the working drawings can be done, it is important that this effort be carried out as quickly and as accurately as possible. Incompatibility between systems can cause serious problems on the job when it is discovered that "things don't fit."

Assuming that a designer has been using an interactive design system and that the information regarding the design is accessible to the computer, compatibility checking can be done with the aid of the machine. One of the first items that can be checked is whether any two systems have members occupying the same physical space according to the drawings proposed. In other words, a pipe isn't shown crossing a space that a beam is supposed to occupy. This type of problem usually is the result of having drawn different things on different drawings.

A simple, but very necessary, check is scanning a check-list to see if all aspects of a building have been taken care of, i.e., washrooms, mail chutes, rubbish disposal, water fountains...and a dozen other items that can easily be overlooked.

The computer programs can also check the actual design against the original objectives to see if the solution developed actually solves the original problem. This involves room areas and volumes, lighting requirements, exposure requirements, etc.

More sophisticated checks can be made to the building codes involved to see if there were any ordinances overlooked or mis-interpreted. This would be particularly useful to firms in metropolitan areas where the same code is used extensively, but it would be hard to implement for a firm that is usually working under different jurisdictions.

It should be noted that all the cross-checking could be done at the same time the architect is doing the design. If, for example, he was designing the kitchen with less floor area than was originally requested, then the programs would signal him that this has happened. The architect would, of course, have the option of changing his kitchen design or telling the computer to forget about the conflict.

A great deal of cross-checking is applicable to the business aspects of architectural practice and falls into the general scheme of an interactive design system.

3. Manufacturer's Data

At the point in the design process when the architect must make the selection of materials, he often refers to information published by the manufacturers of those materials in order to determine which selection to make. Usually this information is stored in pamphlets and brochures that show the product and information about it.

Sweet's catalog file is a very large collection of those pamphlets, arranged by material and manufacturer. Instead of continually thumbing through Sweet's, an architect using a computerized system could request information at any time of the design process. The programs would retrieve the information desired and display it on the screen. The architect could then extract desired information and use it right in his design. This information can be obtained for construction details, specifications, or graphical presentation drawings, and can be taken directly or can be transformed by any of the graphical routines.

4. Architectural Details

For any details that cannot be derived from other sources, an architect can draw his own through the interactive system and then be able to retrieve it as if it were manufacturer's data.

An interesting aspect of the detail process is that, although they are fully annotated with dimensions, material indications and labels, if the detail gets changed, that change shows up in all other places that the detailed item appears.

5. Previous Jobs

Just as detail information is stored, the entire job record, as monitored from the interactive design system, could be stored for later reference. This would be valuable for studying previous jobs of a given type and applying those ideas to a current job. Also, previous jobs can be analyzed to determine inefficient or unproductive areas in the office.

6. Jobs in Progress

The advantage of using a computerized system with current jobs is that the entire office is in communication with each other. People from several disciplines can apply their specialties concurrently to a problem.

7. Specifications

Doing specs by computer will not change the basic methods now employed but will greatly increase the speed and ease of doing them.

The cut-and-paste methods will be greatly simplified by the following steps. To take part of an existing spec (to which the computer has access) and include it in the spec being developed, the architect would:

A) Have the computer put the image of the previous spec on the screen.

B) Circle the section desired.

C) Erase the screen and bring back the spec being developed.

D) Indicate by a mark the position of the desired section.

There are currently on the market several specification systems (some computerized, some not), but the computerized specification of the AIA, MASTERSPEC shows the greatest promise. The author feels, however, that

a computerized specification is of little value unless it is attached to an interactive design system. The reason for this is that a great deal of the spec can be composed by the computer programs as the material selections are made (these would certainly be acceptable as a preliminary spec).

REVIEWS

This paper has outlined many of the concepts and principles involved with a computer-aided design system. The real test of such a system depends on its applicability to the profession. Although it is to be expected that learning to use a new tool like a computer will require some effort, it is unreasonable to ask architects to change their office practice overnight.

This section, therefore, is concerned with reviewing two existing architectural systems in order to provide the interested reader with the information necessary to understand how a system works.

Although both systems to be discussed are architectural in nature, one should not overlook the extensive work in other areas, notably the aerospace and automotive industries. These include NASA, Boeing, Lockeed, Ford, and General Motors. The systems used by those industries are indicative of, in terms of computing power and sophistication, what architects will be using ten years from now.

COMPROSYSTEM:COMputer aided PROfessional Services SYSTEM

Developed by: Design Systems Inc.; Cambridge, Massachusetts
Perry, Dean, and Stewart, Architects
Boston, Massachusetts

COMPROSYSTEM is a set of computer programs used on an in-house computer by the firm of Perry, Dean, and Stewart. Although the system is not as comprehensive nor as sophisticated as some systems, it represents an actual production system being used on a daily basis. They have found that using a computer-aided system has allowed them to have a better understanding of their projects while proving to be cost effective.

The COMPROSYSTEM programs handle a variety of tasks ranging from the assignment of priorities by the architect and client, to development of a design through the presentation stage. The firm uses computer programs to aid them in the following areas:

1. Bubble diagrams
2. Plan configurations
3. Working drawings
4. Mechanical systems and their cost factors
5. Construction details
6. Specifications
7. Presentation drawings
8. Administrative applications
9. Cost estimation and accounting
10. Manpower assignments and costs

An important aspect to remember about this system is that is was designed to be used in an architect's office and, therefore, has sacrificed some academic "goodies" for the sake of more practical concerns. This is particularly true of the cost factors (from updated info stored on tapes) for the major types of building systems that can be used. These cost factors are extremely useful in giving the designer relative cost estimates at the schematic design stage so that expensive solutions can be quickly recognized. These factors provide a more accurate estimate of the actual cost of the proposed building so that bids received are more likely to be in a known range, and they allow the architect to demonstrate to the client the relative and actual costs of various options that may be available to him. This gives the client a better understanding of the costs involved in the design.

For the working drawings application, the firm has stored copies of their most commonly used details on tape. They are easily accessible to the designer while he is designing. The firm has also stored standard space types that can be used in any design in which the designer feels they are applicable. They can then be modified if desired.

The importance of COMPROSYSTEM is that it is an architectural system designed for and by architects. It's use by Perry, Dean, and Stewart is an example of the architectural office of the near future.

ARCHAID: The ARCHitect's computer graphics AID

By: R. Wehrli, M. Smith, Edward F. Smith

Computer Science, University of Utah

The ARCHAID System is an excellent example of an interactive design system. The booklet being reviewed here describes in detail the manner in which a designer would use this system. It is presented here as an example of exactly how such a system is used.

The opening chapter explains the individual physical elements that make up the system; explanations of the equipment, computer languages used, and the general organization of the ARCHAID System.

The next five chapters describe the actual graphical language ("SPACEFORMS") and how it is used. This is a very useful section since it is typical of interactive design systems and will give the un-acquainted architect a better idea of how he uses such a system. Also described are the various options he has in developing his design. A basic vocabulary of objects and actions is defined which becomes the foundation for the designer's work. Thus the designer using ARCHAID can construct, for example, a housing module such as a kitchen, and then can use that kitchen in other houses. The fourth chapter describes the manner of moving the kitchen, scaled or otherwise changed to fit the particular need. There are many actions that can be performed by the system that give a great deal of flexibility to the system.

Of particular interest to the working-drawings phase are the discussions in sections 5.7, 6.8, 8.1 and the figures 2.1-2.7, 5.5-5.8, 6.6, 8.1, 9.12.

These sections describe the manner of using standard details and then changing the standard detail for a specific application. An excellent example (Sec. 5.5, figures 5.5-5.8) is the changing of a window detail that shows up corrected in all other appropriate drawings. The sectioning capability of ARCHAID appears very useful since all the designer must do is place a cutting plane at the desired location and execute the command <CUT> (described in Sec. 4.3) which will then present the sectional view on the display screen. Provisions are also made for dimensioning, lettering, etc., to provide a complete architectural tool.

The ARCHAID System is just one of a number of systems of its type, but it is one of the few systems developed especially for architectural use. The author recommends reading the report as it provides realistic insight into a system that could be a prototype for an office.

CONCLUSION

If the architectural people that read this paper finish it with a feeling that "...I see how it can be done...," then the paper has served its purpose.

The field of architecture is perhaps one of the broadest since it touches every aspect of human life. We are expected to be psychologists, socialists, scientists and so on and so on...until it starts to look like a 27-year curriculum. Architects are largely ineffective because they are "watered down;" they just cannot be masters of all fields. The simplest argument for computers in architecture, therefore, is that they allow the architect the freedom to actually plan environments for people instead of spending the majority of his time cranking out the work associated with those plans.

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13. ABSTRACT

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